A Miniature Ground-Independent Dipole for 40 through 10 Meters

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You may not have the space or the privilege of erecting a full sized antenna. Or, it may be impossible to get a good RF ground at your location. A second- or third-story apartment, fiberglass boat, camper or recreational vehicle, are typical examples. Some hams use mobile whip antennas in such locations. This solution often makes equipment cabinets "hot" with RF, causing annoying RF tingles from the mike, and RFI problems. My miniature dipole solves these problems.

One way to avoid RF in the shack is to use a balanced antenna, like an ordinary dipole. If the dipole is fed with coax and a balun is used at the feed point, the feed line will not be "hot." However, the impedance of a dipole considerably smaller than a half-wave is so high that it is difficult to construct an adequate balun.

Note that, as the antenna becomes shorter, its radiation resistance falls but its capacitive reactance rises. To make the balun reactance five times that of the antenna, an antenna with $-j1250\ \Omega$ of reactance requires a balun reactance of $+j6250\ \Omega$. It is almost impossible to obtain a reactance greater than $+j2500\ \Omega$ from any inductor because the large stray capacitance in the winding resonates with the inductance.[1] If the balun is resonated to obtain the required reactance, its resonant bandwidth is too narrow to be practical.

The impedance of electrically small antennas is difficult to match. A 0.1-λ dipole has an impedance of about $12 - j1250\ \Omega$. When used with 50-Ω feed line, the resulting SWR would be 2609:1! Even if a Transmatch is used in the shack, even a slightly lossy feed line would excessively

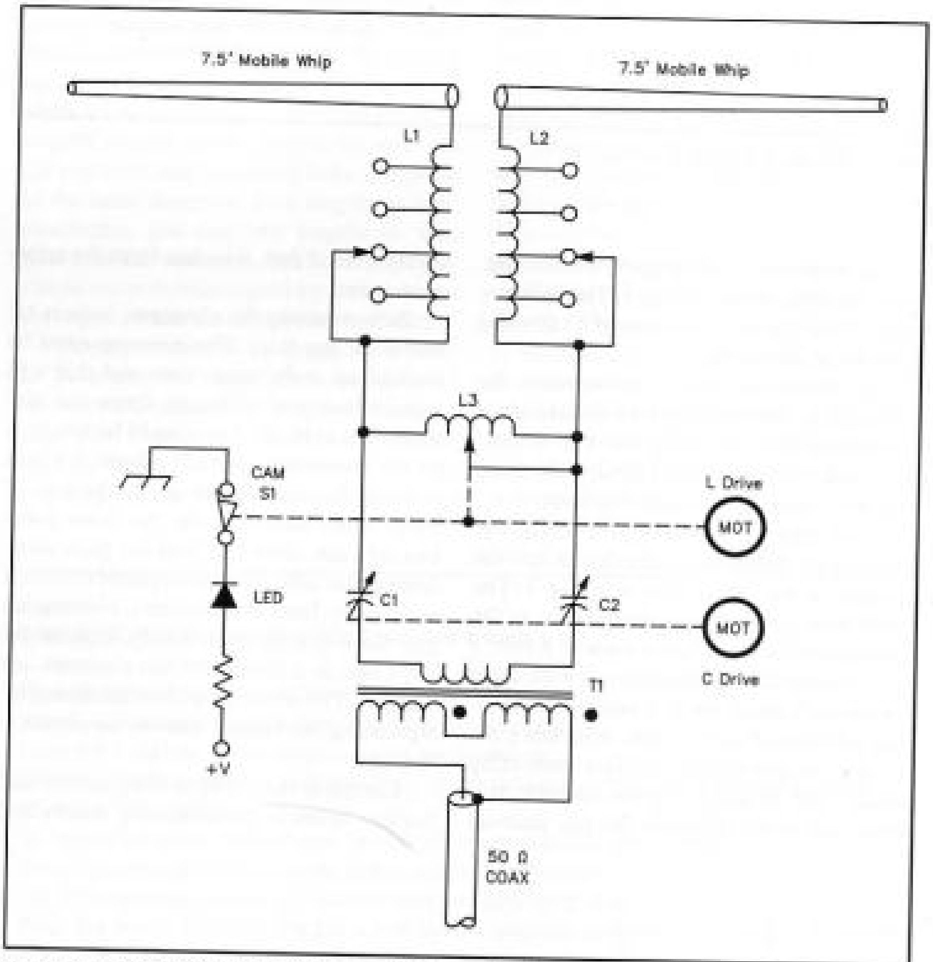

Fig 1—Schematic diagram of the remotely tuned miniature dipole.

C1, C2—30- to 290-pF variable, 0.050-in. spacing, ball-bearing shafts.
L1, L2—28 turns, no. 14 enameled, on 1.5-inch diameter white PVC pipe (10 turns/in.). See text for tap information.
L3—Roller inductor, 16 turns, 10 µH (E. F. Johnson 229-201).
S1—Lever-actuated switch (turns counting).
T1—15 trifilar turns, no. 18 Teflon-insulated hookup wire, on three FT-114-61 cores (µ=125).

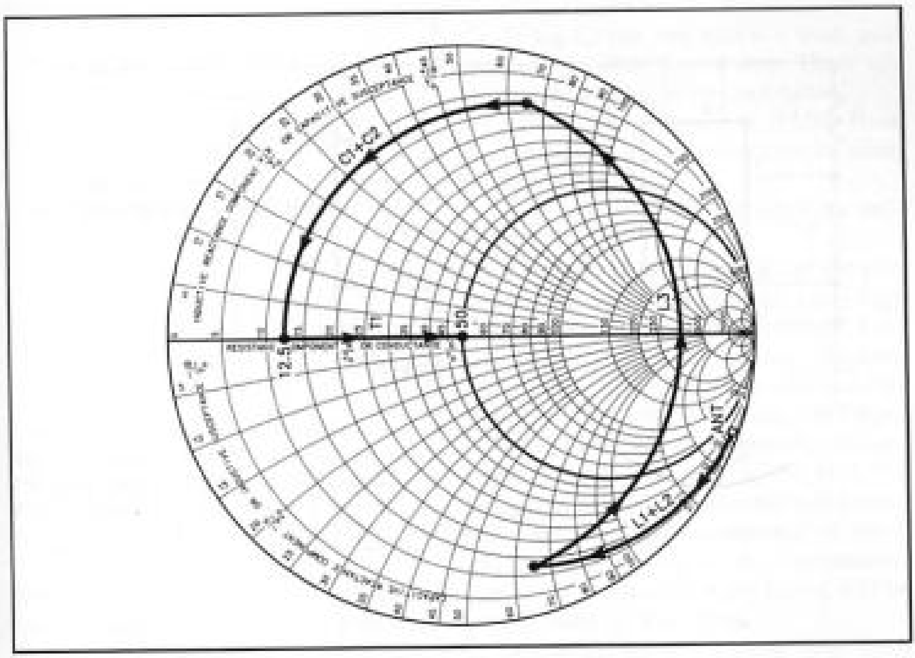

Fig 2—Smith Chart depiction of impedance matching to the miniature dipole.

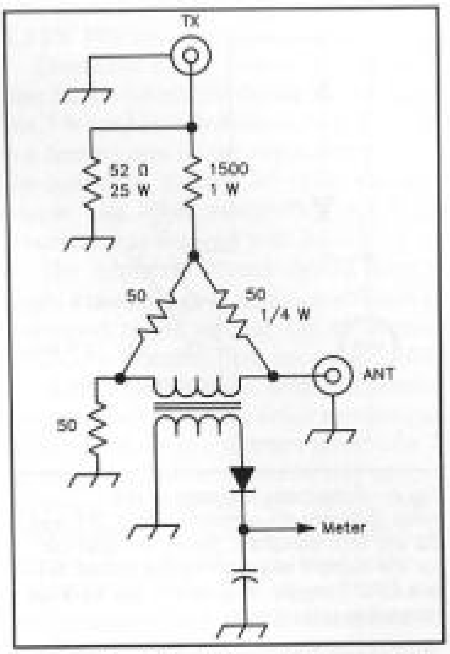

Fig 3—Fixed Wheatstone bridge used for adjusting the antenna at reduced power levels.

reduce radiated power. To get any efficiency at all from such an antenna, you have to match the impedance at the antenna itself.

For example, if you insert a coil of $j1250\ \Omega$ reactance at the antenna, the SWR will be reduced to about 4:1. While this value is still too high for coax line, it is considerably better than the previous example. Of course, with a real inductor, you expect a finite Q and some losses. Suppose we can achieve a Q of 208 in the coil. Now the loss resistance of the coil is 6 Ω and the overall system is 66% efficient, assuming no other losses.

Some mobile antennas and many 160-meter antennas are end loaded, giving a substantial lower section with high current. Such end loading is more efficient than base loading if the coils are of equal Q.[2] However, the presence of a large loading coil near the end of the radiator poses certain physical problems, particularly if the antenna is to be tunable over a wide range of frequencies. In some military applications the antenna must be tunable from 2 to 30 MHz. These applications use a simple whip, tuned with an antenna coupler. Naturally, the tuner must be remotely adjusted or automatically adjust itself.

A Practical Mini Dipole

The basic diagram for the miniature dipole is shown in Fig 1. The radiating elements are two 7.5-ft stainless-steel whips. You can use a fiberglass whip of similar size, but don't use a helically loaded CB whip. Note that coupler symmetry is maintained right to the output transformer.

L1 and L2 represent two base-loading coils. They are not coupled magnetically. The inductances are

Full	14.4 µH
Tap 1	12.4
Tap 2	8.8
Tap 3	4.9
Tap 4	1.7

C1 and C2 are 30 to 290 pF transmitting capacitors with about 0.050-in. spacing. The capacitors should be capable of continuous rotation (more than 360°). The capacitors should be identical and should be locked together at the same capacitance setting.

The capacitors I used are from the BC-458A "Command Set" transmitter (C67). They were used as a fixed padder in the final amplifier tank circuit. Their shafts have ball bearings, although the shafts were locked in place at the factory. L3 could actually be the antenna loading coil from the same set (L5). I had already used L5 in a mobile antenna coupler. T1 is a 12.5- to 50-Ω transformer.

L1 and L2 take some of the curse off the antenna at the low end of the coupler band. They greatly reduce the maximum value of L3 required at the bottom of the band. Shunt coil L3 transforms the impedance to $12.5 + jXXX\ \Omega$ and the series capacitors C1 and C2 cancel the $jXXX$ term (ie, they restore the power factor). T1 transforms the impedance up to $50 + j0$. This matching path is shown schematically on the Smith Chart (Fig 2).

I put taps on L1 and L2 so I could remotely switch them for band changing. In practice however, I found the antenna can be tuned from about 6 through 30 MHz with tap 2 set at 8.8 µH. L3 is a roller inductor. Fig 3 is the schematic of a Wheatstone bridge I use to tune the dipole at low power levels.

Motor Drives

I used small, permanent-magnet dc motors with a speed-reducing gear head in this and other remote-tuning couplers. Output shaft speed should be about 20 r/min, and the motor should run equally well in both directions. You reverse drive direction by reversing the power supply polarity. New motors from Globe or Pittman in a full MIL-SPEC temperature range are quite expensive. Surplus dealers however, may have suitable motors for a few dollars apiece. Remember, the motors must run outdoors in whatever weather your area experiences. Automotive-type motors used for electric windows and antennas will usually operate over a wide temperature range.

Fig 4 shows how I drove the roller inductor (L3). S1 and S2 are microswitches installed at opposite ends of L3. When the roller wheel opens one of the switches, the motor stops. D1 and D2 permit reverse-polarity current to flow around the open switch so the coil can turn in the opposite

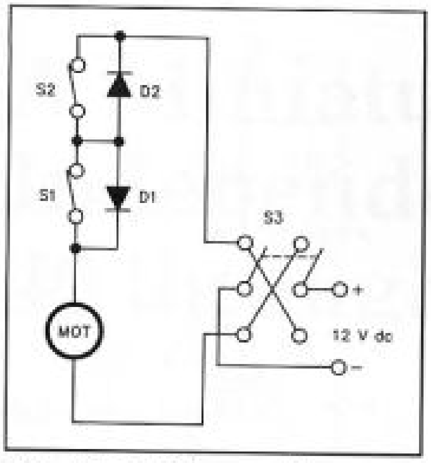

Fig 4—Schematic diagram of the roller-inductor drive-motor circuit. S1 and S2 are limit switches. Select D1 and D2 for the current required by the motor. S3 is a DPDT toggle. The motor is a 12-V dc reversible gear motor.

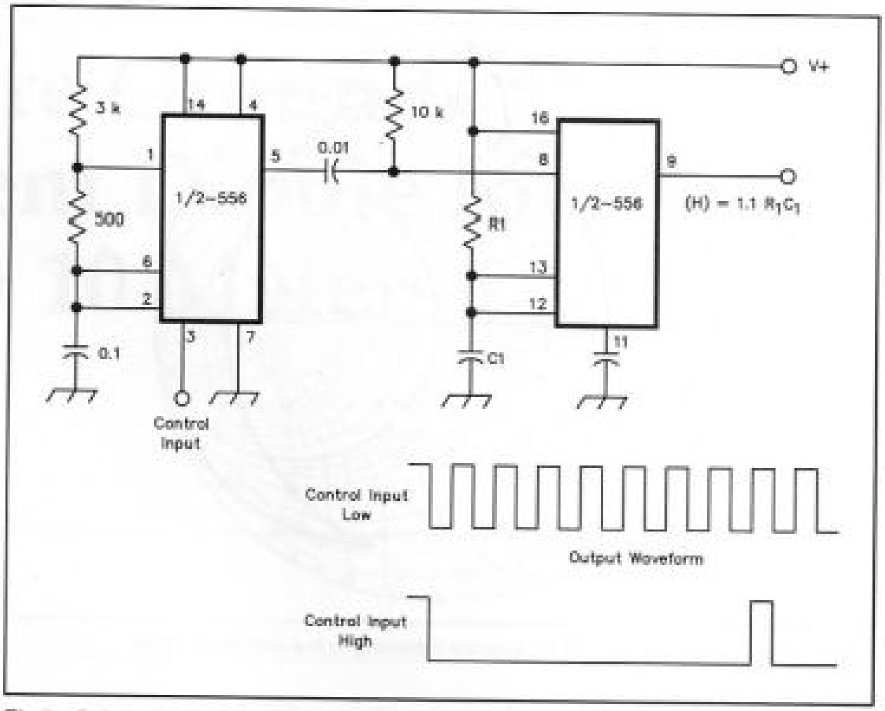

Fig 5—Schematic diagram of the simple pulse-width motor-speed-control circuit. Select R1 and C1 to suit the motor used.

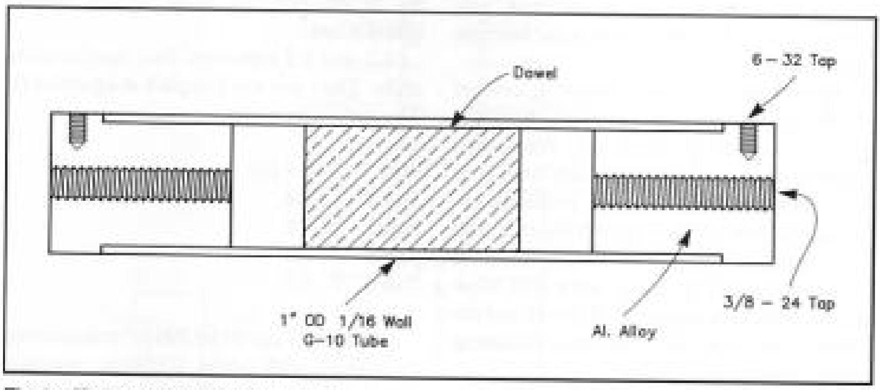

Fig 6—The dipole center insulator.

direction. Both ends of L3 are above RF ground, so the coil shaft must be insulated from the motor and the switches must be insulated from the roller.

For the capacitor drive, a motor speed adequate for the searching is too fast for fine tuning. The circuit of Fig 5 slows the motor so that it can be "tweaked" into position. I don't recommend a series resistor, as it doesn't allow sufficient starting or running torque, especially in cold weather. I have had much more success and satisfaction using this full-voltage pulse-width-modulated circuit. The first half of the 556 sets the pulse rate, and the second half sets the pulse width. Starting torque is superior with this circuit, since the full voltage is available to overcome the voltage drop in the motor brushes.

If the capacitors you use have a shaft on one end only (like the ones I used), join them with insulated couplings and use a drive gear on a shaft between them. The motor will then need a drive gear to mesh with the gear on the capacitors. Note that the capacitors have RF voltage on both their rotors and stators, although the voltage is much lower at the 12.5-Ω end than at the L3 end. When setting up the drive, make sure both capacitors are set to the same capacitance, to maintain circuit balance.

Construction of the Dipole

Fig 6 shows the dipole center insulator, which I made from a piece of thin-wall G-10 tubing. I turned down a maple dowel to fit and epoxied it in place, to prevent crushing the tubing. Then I turned down a pair of aluminum plugs threaded ⅜-24 to fit the ends, and epoxied them in place. The ⅜-24 thread is used on many mobile whips. Two pairs of maple trunnions clamp the insulator to the top of the case.

A pair of G-10 feedthroughs are glued in the back of the case, with a downward slope. The antenna connecting wires are routed through them from the top of the coils, and up to the aluminum plugs into which the radiators screw. A drip loop is arranged in each wire.

The case itself is half-inch weatherproof plywood, with a door opening on the broad face. Build a doorjamb inside the box, on the sides and top. The door overlaps the bottom so that any water inside the box runs out alongside the door. While the seal isn't perfect, I have never found moisture inside the box. I gave the entire box a few coats of white latex house paint.

The coupler parts are mounted on a large Plexiglas plate, ¼-in. thick. The plate is secured in the box with four screws. For servicing, the entire works can be removed.

The horizontal whips droop about 5 in. at the tips. The droop has little effect on performance, and has the advantage that rainwater runs off the tips, rather than to the center and across the insulator.

RF enters through a close-fit hole around the PL-259. The control cable fits through a notch in the doorjamb. Make sure no significant holes are open to the outside; otherwise you'll find wasps the next time you open the box!

The box has a NURAIL fitting on the back to clamp it to a 2-in. aluminum mast, which is hinged at the bottom. The mast is

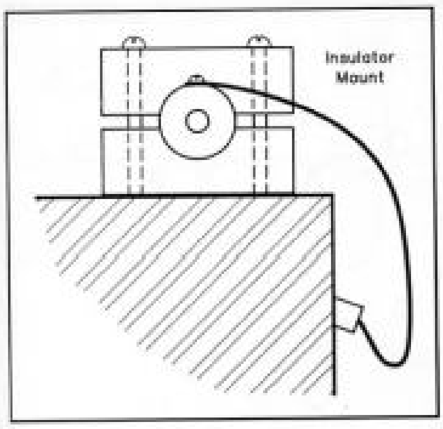

Fig 7—Mounting the center insulator to the box containing the tuning capacitors and inductors.

about 20 feet long. With the hinge and the box extension, the dipoles wind up about 24 ft above ground.

Tuning Up

The cam on the inductor shaft actuates a turns counter. The LED flashes once per revolution. The tune-up procedure follows.

1) Run L3 to the low-inductance end stop.

2) Turn on the capacitor drive motor so that C1 and C2 continuously rotate.

3) Jog L3 out, one turn at a time, until you see the SWR start to drop. There will be two dips per capacitor revolution.

4) Stop the capacitor motor from searching and jog the capacitors for minimum SWR.

5) Fine tune L3 and the capacitor until the SWR is 1:1.

From this description you can see your transmitter will be exposed to a very high SWR during tuneup. For this reason, I use the circuit of Fig 3 for tune-up. The fixed Wheatstone bridge detects a matched condition on the antenna. The detector output is proportional to the voltage-reflection coefficient, and goes to zero at $50 + j0\ \Omega$. The padder isolates the transmitter and attenuates the signal to the antenna by about 30 dB. This action protects your transmitter, and the relatively quiet tuning will be appreciated by other hams.

I constructed my dummy load from 2-watt composition resistors in series-parallel. Once the antenna is tuned, the pad is bypassed by a switch not shown in the diagram.

Results

I have used the antenna for some time on 40 through 10 meters. I use it most often on 40 and 20. I have pumped as much as 1.5 kW PEP into it with no signs of arcing.

Compared with a 36-foot vertical with nine buried radials, the dipole is much "less hot." When I installed the vertical, I had to put ferrite cores on the control cables and the feed coax, to keep RF off the microphone and other equipment. No such treatment was required with the dipole.

The miniature dipole should have a slight disadvantage in radiation efficiency, compared to the vertical. On 40 meters, efficiency probably does not exceed 66% or –1.8 dB. Nevertheless, in several months of operation I found that either antenna can be better on a given path at a given time. I do find the dipole is a considerably quieter receiving antenna than the vertical, however (typically 5 to 6 dB), particularly in the presence of locally generated noise.

All in all, I am quite pleased with the performance of this antenna. I recommend it to anyone with space or grounding limitations.

Notes

[1]J. A. Kuecken, *Antennas and Transmission Lines* (Indianapolis: Howard W. Sams), Ch 24, "Reactive Elements and Impedance Limits."

[2]G. L. Hall, Ed., *The ARRL Antenna Book* (Newington: ARRL, 1982).